

OPERATIONAL GUIDANCE TO IMPROVE INDUSTRY BENEFIT OF ALTERNATE EQUIPMENT AND STRATEGIES

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Abstract: The PWROG has recently championed several efforts to increase collaboration between Probabilistic Risk Assessment (PRA) experts and nuclear power plant operators and procedure writers. The result of these efforts has allowed for nuclear power plants to risk inform plant procedures to reduce risk and promote the health and safety of the public. A key insight from this collaboration was the need for, and development of, an industry framework for generating WRITTEN GUIDANCE to increase the benefit of alternate strategies. As the industry expands the use of alternate equipment (installed and portable), standardization of terminology, application, and PRA modeling of flexible equipment operation is desired. To that end, a new category of industry Guidelines has been defined: “Flex Support Guidelines Additional Defense in Depth” (FSG+DD). The new guideline categorization maximizes the use of defense in depth and minimizes the need for flexible equipment to fall into regulatory required maintenance (Maintenance Rule Scope). FSG+DD strategies may be utilized to supplement current guidance used to maintain or restore a function when the plant is outside a Design Basis CREDITED MITIGATION STRATEGY. Additionally, these strategies may be utilized within a plants Design Basis to compensate for equipment that is DEGRADED or out of service to maintain a function. This paper will discuss the Risk Informed Procedure Writers Guide developed by the PWROG to form the framework for the industry’s expanded use of flexible equipment.

1. INTRODUCTION

The use of portable equipment via Flex Support Guidelines (FSG’s) was postulated by the U.S. Nuclear Regulatory Commission (NRC) in the wake of Fukushima Daiichi accident to address beyond-design-basis accidents and improve plant flexibility. FLEX equipment such as portable pumps, generators, batteries, and other supporting equipment or tools, are all maintained and stored in a dedicated and secure building designed to withstand external hazards. These FLEX assets are rarely utilized at the sites.

The PWROG has developed a standardized methodology for generating WRITTEN GUIDANCE that utilizes manual actions and portable equipment such as FLEX to improve site operations and accident mitigation. These improvement areas could include, but are not limited to, the following:

- Providing additional defense in depth during Emergency Operations
- Online risk reduction
- Outage risk reduction
- Generation risk reduction
- Maintenance activity efficiency
- Maintaining SSC Availability
- Supporting a Notice of Enforcement Discretion (NOED)
- Supporting Significance Determination Process
- Supporting Risk Informed Completion Times (RICT)

A Risk Informed Procedure Writers Guide is being generated to capture the insights.

2. DEFINITIONS:

Expanding the use of portable equipment and utilizing operator actions to maintain equipment available requires defining some terms to ensure consistent industry application. The following terms are defined for this purpose:

- a. ACCESSABLE: Locations outside the control room that are required for access for performance of MANUAL ACTION, must adequately protect personnel from the environmental and radiological conditions caused by the event. Also, the path to perform the action (ingress, performance, and egress) must not be hindered by environmental conditions (temperature, radiation, water levels, etc.) or other equipment (scaffolding, etc.). Ventilation must be verified to not impede the access (e.g., opening of doors against a pressure differential) to areas where equipment is to be operated. Additionally, if the plant conditions associated with a MANUAL ACTION require Personal Protective Equipment (PPE) then PPE/FPE donning should be considered before MANUAL ACTION is allowed.
- b. ADEQUATE COMMUNICATION: Predetermined communication method to be used between the control room and the ASSIGNED OPERATOR to ensure the restoration actions are initiated and reported back when required. The communication method used must consider the reliability of the communication method following the accident (e.g., loss of power effect on phone network or background noise), the necessity of communication, and AVAILABLE TIME.
- c. ASSIGNED OPERATOR: Individuals who are qualified to perform and briefed on the required actions to restore the function. In most cases this is a single person but more than one may be required and credited. The ASSIGNED OPERATOR does not have to be a plant operator. For example, any plant employee could be assigned to close a vent door following an accident if they understand their responsibility. ASSIGNED OPERATOR encompasses the terms “Dedicated Operator” and “Designated Operator”, as used in other industry documents.
- d. AVAILABLE TIME: The time interval from the cue to perform the manual action to the time that analysis credits completion of the action. For (a)(4) purposes, this includes T_{cog} plus T_{exe} which must be less than T_{sw} minus T_{delay} . For (a)(1)/ (2) the AVAILABLE TIME is determined within the USAR and/or MR scoping documents.
- e. BEYOND DESIGN BASIS EVENT (BDBE): These events and mitigation/management documents associated with these events are listed in 10 CFR 50.155, Mitigation of Beyond-Design-Basis Events which include ELAP (FLEX), LOLA (EDMG) and Core Damage (SAMG). However, BDB guidance is currently contained in DBE plant documents (see CREDITED MITIGATION STRATEGY for additional discussion).
- f. CONNECTED: Portable equipment is considered CONNECTED to installed equipment when it results in inoperability or unavailability of the installed system or component due to seismic, isolation, ventilation, barrier impairment or other concerns. CONNECTED Equipment should not, however, prevent transition to the next credited strategy at the appropriate threshold (E.g., Feed and Bleed Core Cooling).
- g. CREDITED MITIGATION STRATEGY: The strategy contained in site specific documents which has been approved, verified, and validated (as applicable) to mitigate design basis accidents described in the FSAR and some licensing basis events. It is important to understand that DBE mitigation documents (such as EOPs) will always direct the CREDITED MITIGATION STRATEGY; however, EOPs may also contain alternate strategies should the credited strategy NOT be able to be performed. The alternate strategies may be contained in Response Not Obtained or Contingency actions in optimal recovery EOPs. Alternate strategies to maintain plant functions critical to health and safety of the public may be contained in the EOP Functional Recovery Guidelines.

- h. DEGRADED: This category of SSCs fits in neither MAINTENANCE or TESTING however availability still applies and MANUAL ACTION may be desired to enhance, establish, or maintain availability.
- i. DESIGN BASIS EVENT (DBE): Events for which the plant is designed to mitigate. These are normally described in the Accident Analysis chapter of the FSAR.
- j. DIAGNOSIS: Requires complex thought and decision making to identify the reason for the failure by evaluation of the symptoms. Procedural response to an alarm or performance of “IF/THEN” steps would NOT be considered DIAGNOSIS.
- k. EXTENDED LOSS OF ALL AC POWER (ELAP): BDBE associated with external hazards of a type or magnitude outside the plant design basis as described in 10 CFR 50.155.
- l. EXTENSIVE DAMAGE MITIGATION GUIDELINES (EDMG): Strategies and guidelines to maintain or restore core cooling, containment, and spent fuel pool cooling capabilities under the circumstances associated with loss of large areas of the plant impacted by the event, due to explosions or fire, as required by 10 CFR 50.155(b)(2).
- m. FLEX EQUIPMENT: Equipment credited for use in the FLEX SUPPORT GUIDELINES as specified in the utility specific FLEX Implementation Plan.
- n. FLEX SUPPORT GUIDELINES (FSG): Strategies and guidelines to mitigate beyond-design-basis external events from natural phenomena that are developed assuming a loss of all ac power concurrent with either a loss of normal access to the ultimate heat sink or, for passive reactor designs, a loss of normal access to the normal heat sink as required by 10 CFR 50.155(b)(1).
- o. FLEX SUPPORT GUIDELINES ADDITIONAL DEFENSE IN DEPTH (FSG+DD): Guidelines to utilize alternate equipment (installed or portable) to provide additional defense in depth to maintain or restore a function including support of Emergency Operating Procedures. FSG+DD guidelines are additional defense in depth strategies which may be utilized as outlined within this document. These are NOT the FSGs developed for compliance with 10 CFR 50.155(b)(1).
- p. IN SERVICE Alternate (including portable) equipment is considered IN SERVICE if it is performing the credited function.
- q. INTENDED FUNCTION Typically as defined within the USAR and/or MR scoping documents and may or may not include an AVAILABLE TIME.
- r. LOCAL ACTION Action(s) required to be taken outside of the Control Room
- s. LOSS OF LARGE AREA (LOLA): BDBE associated with manmade damage to large areas of the plant site due to fire or explosion as described in 10 CFR 50.155.
- t. MAINTENANCE SSC is currently undergoing corrective or preventive maintenance or repair. An SSC may or may not be TAGGED OUT while undergoing MAINTENANCE. Therefore, for the purposes of this guideline, availability may be applicable even if the SSC is undergoing MAINTENANCE as long as the function can be restored within the AVAILABLE TIME.
- u. MANUAL ACTION Actions taken by operators or other qualified persons to satisfy a design or credited function. Manual actions can be utilized in leu of automatic action to satisfy availability however this term is not limited to these times. MANUAL ACTION can also be prescribed as a compensatory measure for a DEGRADED condition not involving an automatic action or even as a defense in depth or prudent measure to enhance risk or maintain equipment available.
- v. PRA CREDITED FUNCTION Typically as defined within the PRA model (notebook) and may or may not include an AVAILABLE TIME.

- w. REPAIR Requires complex maintenance actions, parts, tools, and work plans to restore the function. UNCOMPLICATED maintenance actions which are contained in Written Instructions and are capable of being performed within the AVAILABLE TIME would not necessarily be considered REPAIR.
- x. STAGED: Portable Equipment is considered STAGED if it is Capable of being CONNECTED and performing the credited function within AVAILABLE TIME. This may or may not require physical movement of equipment. FLEX EQUIPMENT may remain available for ELAP if STAGED.
- y. SEVERE ACCIDENT MANAGEMENT GUIDELINES (SAMG): BDBE guidelines designed to manage the release of radioactivity following a core damage event.
- z. SYSTEM STRUCTURE OR COMPONENT (SSC): System structure or component for which availability is in question. An SSC could be Tech Spec related or not Tech Spec related for availability to apply.
- aa. TAGGED OUT: Out of service for corrective or preventive MAINTENANCE or TESTING so that it cannot promptly be restored should the need arise. Generally speaking, danger tags prevent rapid restoration and would normally represent a condition where an SSC cannot be relied upon to perform its functions. Caution tags, on the other hand, do not prevent operation of the component and the SSC would not normally be considered TAGGED OUT in the context of this guideline. Additionally, this term, as used in this guideline, is intended to help differentiate between MAINTENANCE, TESTING, and DEGRADED (terms also defined). It is assumed that if an SSC is TAGGED OUT, it is considered OOS for corrective or preventive maintenance and the provision to use MANUAL ACTION is not allowed.
- bb. TESTING: Includes Surveillance Testing, Post-maintenance Testing, Return to Service Testing, and Special Testing such as troubleshooting activities being controlled under a procedure or work plan.
- cc. UNCOMPLICATED: Usually intended to mean a single action or a few simple actions however a risk-based approach can be used to determine if the steps can be considered UNCOMPLICATED. For example, if there are multiple steps (more than “a few”) required to restore the function, but there are recovery actions or self-revealing indications such as alarms which would virtually ensure success before the AVAILABLE TIME, the actions could still be considered UNCOMPLICATED.
- dd. USAR DESIGN FUNCTIONS: Most SSCs installed in the plant, whether Safety Related or not, have some sort of description within the USAR. From this description, one should be able to glean its direct design functions or how an SSC supports other design functions, some of which may be safety related and/or within the scope of the Maintenance Rule. Note that some SSCs have multiple design functions, and each must be assessed separately for impact on availability. An example would be a motor valve which has an open function to provide flow for certain events/conditions and a closed function to isolate flow under other events/conditions. Help for determining USAR DESIGN FUNCTIONS can be obtained from plant engineering staff.
- ee. WRITTEN GUIDANCE Written instruction that has been reviewed, evaluated, and credited based on their clarity and effectiveness. For guidance generated with specific steps to establish or restore a function it is recognized that not all instructions will be contained within plant procedures, however other written instructions may be implemented to deliver the same level of clarity.

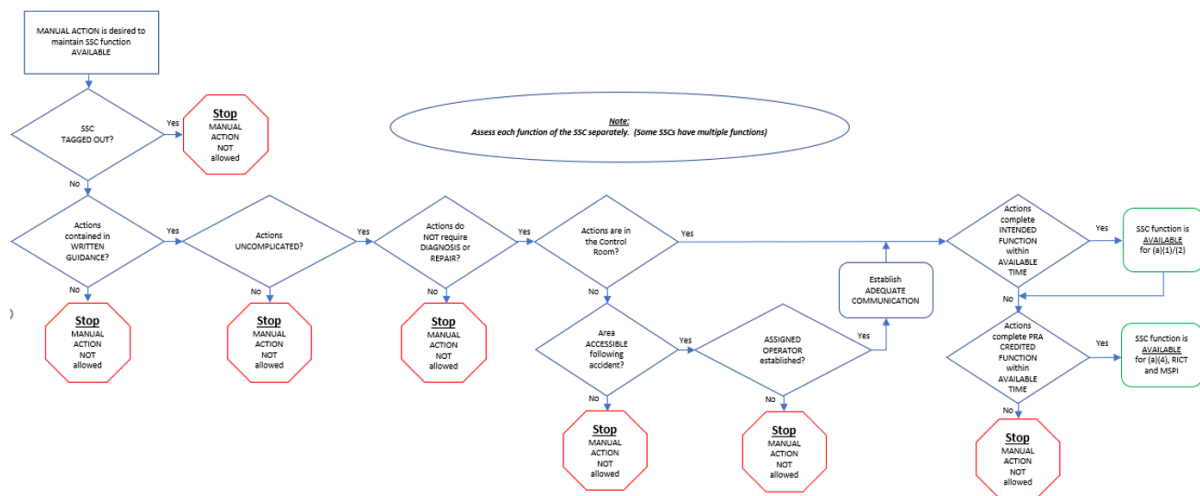
Defined terms will be expressed in ALL CAPS throughout this document.

3. CREDITING MANUAL ACTIONS TO MAINTAIN SSC FUNCTION AVAILABLE

When an SSC must be rendered temporarily unavailable due to maintenance or testing, the SCC may be considered Available by crediting installed or portable equipment to restore the SSC within the AVAILABLE TIME.

- a. Some SSCs have multiple functions, and each function should be assessed separately.
- b. Consider the following at a minimum:
 1. Actions are contained in WRITTEN GUIDANCE
 2. SSC is NOT TAGGED OUT
 3. Actions do not require DIAGNOSIS or REPAIR
 4. Actions to restore the PRA CREDITED FUNCTION within the AVAILABLE TIME
 - ASSIGNED OPERATOR is Briefed, Designated or Dedicated such that the action can be accomplished
 - ADEQUATE COMMUNICATION is established

Figure 1 - Assessment of Manual Action to Maintain SSC Function Available



4. FLEX SUPPORT GUIDELINES ADDITIONAL DEFENSE IN DEPTH (FSG+DD)

A consistent framework has been developed for the industry to follow when identifying additional defense in depth opportunities including during the execution of Emergency Operating Procedures (EOP). WRITTEN GUIDANCE to utilize alternate equipment (installed or portable) to provide additional defense in depth to maintain or restore a function will be referenced as FSG+DD (FLEX Support Guidelines Additional Defense in Depth) including when the guidance is utilized in an EOP. FSG+DD strategies may be utilized to compensate for equipment that is inoperable and unavailable when the plant is operating within the design basis. Additionally, FSG+DD strategies may be utilized to supplement current guidance used to maintain or restore a function when the plant is outside a DBE credited mitigating strategy (such as EOP Response Not Obtained (Contingency) actions and Functional Recovery Guides). FSG+DDs are NOT the FSGs developed for compliance with the ELAP DBE requirements of 10 CFR 50.155(b)(1) [1].

FSG+DD guidance can be implemented as mitigating strategies, as defined in NEI 16-06 [2], when they are providing a safety function or implemented as efficiency strategies to provide improvements to plant operations. FSG+DD guidance identified for risk reduction is intended to be used in conjunction with NEI 16-06 to establish regulatory or operational risk reduction credit such as crediting FSG+DD guidance in a plant probabilistic risk assessment (PRA).

4.1 Incorporating FSG+DD Guidance in Existing Plant Documents

FSG+DD guidance may either be added into existing plant documents including but not limited to EOPs, AOPs, ARPs, NOPs, etc or it may be standalone if incorporating into existing documents is not practical.

For consistency and to maintain compliance with discussions associated with the equipment “Used in an EOP” with regards to the Maintenance Rule, the guidance will always be referenced as FSG+DD and utilized as an additional level of defense in depth to maintain or recover a function.

4.2 FSG+DD Impact on DBE Credited Mitigation Considerations

The design basis of the plant is governed by the FSAR and Technical Specifications. Implementation of an FSG+DD strategy should be evaluated to ensure that it does not prevent the successful operation of available installed plant equipment credited in the design basis. Portable equipment should not be used to replace the available minimum installed equipment required by the plant Technical Specifications or the accident analysis chapter of the FSAR.

Additionally, potential impact on Time Critical and Time Sensitive actions should be evaluated prior to implementation of an FSG+DD strategy.

4.3 FSG+DD Maintenance Rule Considerations

The following guidance is derived from language contained in Regulatory Guide 1.160 [3] and extends the philosophy utilized for FSGs to FSG+DD guidance:

- When steps are added to an EOP only to direct to FSG+DD guidance for implementing non-safety related SSCs, those SSCs should not be considered used in the EOP, if the changes associated with these steps made to the EOP do not impede the successful implementation of other SSCs used in the EOP. An appropriate technical basis should be documented that demonstrates that these changes do not impede the successful implementation of the other SSCs. These uses of non-safety related SSCs should be evaluated against all other 10 CFR 50.65(b) scoping criteria.
- The following two items apply when EOP steps are added that direct operators to FSG+DD guidance. If these are met, then the non-safety-related equipment in the FSG+DD is not considered “used” in the EOPs:
 - Differentiate the non-safety-related equipment in the FSG+DD from the equipment providing EOP mitigation function in the Maintenance Rule scoping evaluation or EOP change process documentation.
 - Equipment already scoped into the Maintenance Rule under the “used in plant EOPs” criteria should not be removed from the Maintenance Rule scope based solely on the addition of non-safety-related equipment in the FSG+DD.
- The above language applies to the use of non-safety related equipment implemented by FSG+DD guidance in a design basis accident.

- “Mitigate or Mitigating” is defined as “actions or steps taken to lessen the severity or the adverse consequences of the event/symptom that necessitated entry into the EOP.” While it is true that utilizing the FSG+DD could lessen the severity or the adverse consequences of the initiating event or symptom that led into the EOPs, the FSG+DD is not required to mitigate the within-design-basis accidents addressed by the EOPs; the FSG+DD guidance is not essential to or relied upon for the successful mitigation. Therefore, FSG+DD guidance used to address a beyond-design-basis condition is not required to perform the EOP mitigating function and is not “used” for that purpose. Accordingly, it’s not scoped into the Maintenance rule under 50.65(b)(2)(i).
- Once the credited FSG+DD strategy is used to improve the PRA results and downstream applications it must be considered for availability to be a viable defense in depth strategy. If for some reason, the FSG+DD strategy is determined to be unavailable then the credit modeled must be removed from the baseline PRA results. For example, if the PRA is modeled to credit an FSG+DD cooling line the design basis cooling line fails then the availability of the FSG+DD cooling line must be considered in the real time risk model. In other words, if the FSG+DD strategy has a significant impact on the baseline risk model then its availability needs to be incorporated into the real time plant configuration assessment. This is consistent with 10 CFR 50.65 (a)4 requirement to analyze the real time configuration of the plant. Therefore, the sensitivity of conditions that would render the FSG+DD strategy unavailable should be commensurate with the overall impact the FSG+DD strategy has on the overall plant risk.

4.4 FSG+DD Strategies Supporting Partial Loss of Function

- a. FSG+DD guidance may be utilized to restore a partial loss of function, or in support of maintenance activities if the following conditions are met:
 - The SSC (component, train, bus, channel) on which the FSG+DD guidance will be utilized is/will be inoperable AND unavailable
 - Operable SSCs AND applicable implementation strategy credited for maintaining or restoring the partially lost function are unaffected by the FSG+DD guidance (i.e., opposite train equipment)
- b. If a CREDITED MITIGATION STRATEGY is unavailable (i.e opposite train equipment), FSG+DD guidance may be utilized to restore the function. However, the FSG+DD guidance should not impact transition to the next credited strategy if required (e.g., if all installed feedwater is lost a portable feedwater FSG+DD option may be utilized, but the transition to Feed and Bleed cooling must not be impacted)
- c. Portable equipment must be capable of being STAGED, CONNECTED, and placed IN SERVICE to restore the lost function within the AVAILABLE TIME by the WRITTEN GUIDANCE. Otherwise, consider pre-staging the portable equipment.
- d. FSG+DD equipment must be maintained while IN SERVICE. Guidance should be established to maintain the equipment. (e.g., Refueling Requirements or Cold Weather Protection).
- e. When the FSG+DD equipment is no longer required to maintain the function, the FSG+DD guidance must restore the SSC to the as found condition.
- f. If FLEX EQUIPMENT is deployed such that less than the minimum required for ELAP mitigation is available, WRITTEN GUIDANCE must be available for returning the FLEX EQUIPMENT for use in the original ELAP mitigation strategy. The guidance must enable successful STAGING, CONNECTING, and placing IN SERVICE within the AVAILABLE TIME. Additionally, if FLEX equipment is utilized solely for O&M flexibility purposes, the capability of restoring of N+1 should be available.

4.5 FSG+DD Strategies Supporting Security Response

FSG+DD strategies can be utilized to optimize plant physical security. Idaho National Laboratory (INL) report, Integration of FLEX Equipment and Operator Actions in Plant Force-On-Force Models with Dynamic Risk Assessment [4] integrates commercial Force-on Force modelling tools with INLs FLEX deployment model. The results demonstrate that, even in the extreme case of a successful adversarial attack, deployment of portable equipment can result in a significantly high likelihood of preventing radiological release. Manual actions to utilize FSG+DD strategies can be deployed from the time the adversaries are neutralized and prior to catastrophic failure and radioactive release. The FSG+DD strategies can restore power and provide core cooling preventing core damage.

The use of FSG+DD strategies will improve plant physical security enabling a staffing reduction and ultimately a site cost savings.

4.6 FSG+DD Strategies Supporting Fire Response

FSG+DD strategies may be utilized to restore a function lost due to a fire. Fire response procedures and Pre-Plans may contain WRITTEN GUIDANCE to utilize FSG+DD strategies to replace equipment affected by the fire.

4.7 FSG+DD Strategies for TS Allowed Outage Time (AOT) Extension and Shutdown Risk Reduction

FSG+DD strategies can be leveraged to enable online maintenance of installed equipment by incorporating into the plant PRA model and comparing the resulting risk-achievement-worth (RAW) to the risk acceptance guideline in the NRC regulation RG1.177 “An approach for Plant Specific, Risk-Informed Decision making: Technical Specifications” [5]. The resulting AOT extension using FSG+DD strategies may shift component maintenance from a refueling outage period to online maintenance. This maintenance scheme may reduce the burden of outage maintenance, allow more effective outage planning, and increase an NPP’s capacity factor. Idaho National Laboratory report, Utilizing FLEX Equipment for Operations and Maintenance Cost Reduction in Nuclear Power Plants [6] introduces this concept and presents the risk and cost analysis framework for expanding the use of FLEX Strategies. FSG+DD strategies can extend this concept to additional installed plant equipment and portable equipment.

4.8 Opportunities for Utilizing FSG+DD Strategies

- a. Restoration/maintenance of dc or vital ac systems to restore instrumentation and dc functions
- b. Restoration/maintenance of core cooling
- c. Restoration of RCS inventory and reactivity control
- d. Maintenance of containment function
- e. Restoration of Spent Fuel Pool (SFP) makeup
- f. Stage portable diesel generators during safety-related plant diesel generator outages to provide defense-in-depth
- g. Use a portable diesel generator during security diesel generator outage
- h. Stage a portable pump to provide defense-in-depth for spent fuel pool inventory control or use it to provide temperature control

- i. Use a portable pump to fill accumulators, safety injection tanks, or core flood tanks
- j. Stage a portable pump to provide defense-in-depth for a DEGRADED safety related pump
- k. Use a portable pump to augment a DEGRADED non safety related pump
- l. Stage a portable pump to provide defense-in-depth for Reactor Coolant System (RCS) reactivity and RCS inventory safety functions
- m. Use a portable pump to drain and fill RCS, suppression pool or auxiliary systems
- n. Use a portable air compressor while plant air compressor is unavailable to avoid reactor trip
- o. Stage a portable pump to feed the steam generators to provide defense-in-depth or use it to add chemicals
- p. Use a portable battery bank to support replacement of installed battery banks
- q. Use a temporary power supply to power instrumentation and control (I&C) or plant loads during power supply outages
- r. Use of portable fans for room cooling on loss of normal Heating, Ventilation, and Air Conditioning (HVAC)

5. CONCLUSION

The industries considerable investment in FLEX assets are currently underutilized. The PWROG has developed a standardized methodology for generating WRITTEN GUIDANCE that utilizes manual actions and FSG+DD strategies to improve site operations and accident mitigation. This guidance will be available to the industry via a Risk Informed Procedure Writers Guide.

Acknowledgements

PWROG Risk beneficial Procedure Change Subcommittee, consisting of Procedures and Risk Committee Volunteers.

References

- [1] 10 CFR 50-155, Mitigation of Beyond-Design-Basis Events, August 2019 (84 FR 39684)
- [2] NEI 16-06, Crediting Mitigating Strategies in Risk Informed Decision-Making, Revision 0, August 2016
- [3] Regulatory Guide 1.160 Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, Revision 4, August 2018
- [4] Idaho National Laboratory report INL/EXT-20-59510, Integration of FLEX Equipment and Operator Actions in Plant Force-On-Force Models with Dynamic Risk Assessment, Revision 0, August 2020
- [5] NRC, "An Approach for Plant-Specific, Risk-Informed Decision Making: Technical Specifications," Rev. 1, Regulatory Guide 1.177, 2011.
- [6] Idaho National Laboratory report INL/EXT-19-55445, Utilizing FLEX Equipment for Operations and Maintenance Cost Reduction in Nuclear Power Plants, Revision 0, August 2019